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# A surficial electrical resistivity survey east of the Sheffield low-level radioactive waste disposal site, Bureau County, Illinois

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December 1981

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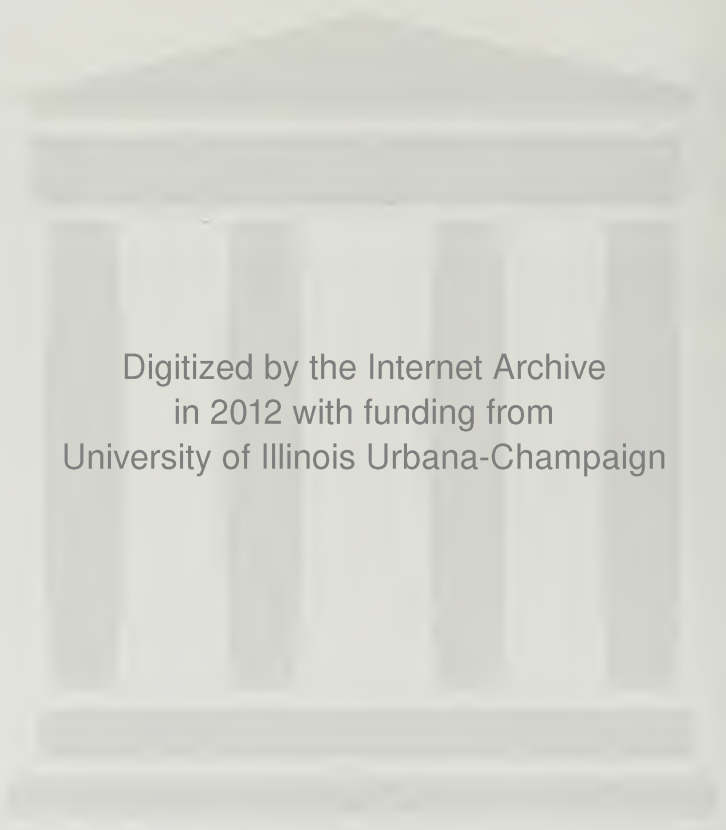
*Figures: Pat Whelan*

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# A surficial electrical resistivity survey east of the Sheffield low-level radioactive waste disposal site, Bureau County, Illinois

## ABSTRACT

*An electrical earth resistivity survey was conducted over an area adjacent to the Sheffield low-level radioactive waste disposal site in Bureau County, Illinois. The purpose of the survey was to determine the extent of a deposit of sand belonging to the Toulon Member of the Glasford Formation that was originally encountered in borings and tunnels at the disposal site. The survey was undertaken at the request of the USGS in order to assist in planning an exploratory drilling program in the vicinity of the Sheffield disposal site. The survey was successful in tracing the outline of the sand unit in the area; its thickness is estimated to range from 0 to 12 m (0 to 40 ft) at depths of 0 to 7 m (0 to 23 ft). There is some evidence to suggest that portions of this sand unit are presently undergoing erosion.*

## INTRODUCTION

An electrical earth resistivity survey was conducted in the SW $\frac{1}{4}$  NW $\frac{1}{4}$  SE $\frac{1}{4}$  Section 26, T. 16 N., R. 6 E., Bureau County, on August 4-5, 1981. The purpose of the survey was to determine the extent of a sand deposit originally encountered in borings and tunnels at the Sheffield low-level radioactive waste disposal site. The results of the survey are to be used by the U.S. Geological Survey to aid in planning an extensive program of stratigraphic test drilling.

The survey was conducted in a gently sloping pasture adjacent to the Sheffield disposal site. The land surface slopes east and north toward an area disturbed by surface mining of the Herrin (No. 6) Coal Member (Smith and Berggren, 1963). The land surface is poorly vegetated with several well-developed gullies.

## GEOLOGY

The site is underlain by unconsolidated glacial sediments of Wisconsinan and Illinoian age resting on Pennsylvanian bedrock. The Pleistocene stratigraphy of the Sheffield disposal site has been summarized by Foster and Erickson (1980). Their description of samples from USGS well 501, located 15 meters (50 ft) west of the southwest corner of the survey area (fig. 1), is used as a geologic control for this study. The Pennsylvanian rocks were not sampled in this well; however, exploratory boring B (ISGS county no. 334), located 30 meters (100 ft) southwest of the survey area, did penetrate 76 meters (250 ft) of Pennsylvanian strata.

The uppermost bedrock is shale of the McLeansboro Group (Willman and others, 1975), which overlies rocks of the Carbondale Formation, including the Herrin (No. 6) Coal. The Herrin Coal was encountered in boring B at a depth of 29.7 to 31.4 meters (97.5 to 103 ft).

The Pleistocene sediments penetrated by USGS well 501 consist of 4.6 meters (15 ft) of Peoria Loess overlying three members of the Glasford Formation. The upper and lower members are the Radnor and Hulick Tills, respectively. The middle member in this sequence, the Toulon Member, is a channel-like outwash deposit. This pebbly sand, lying at an elevation of 746 to 732 feet, is the main target horizon of this report.

## RESISTIVITY SURVEY

The electrical resistivity survey provides a means of shallow subsurface exploration by the utilization of electrical measurements taken at the surface of the earth. An electrical current is forced to flow through the earth between two electrodes pushed into the ground. The voltage-drop created by this current flow is measured across two other electrodes. The electrode array is expanded after each measurement in order to increase the depth of penetration of the current, and consequently, provide information from greater depths in the earth. This field method is known as Vertical Electrical Sounding (VES). The two measured quantities of current and voltage-drop are related to the resistivity through Ohm's Law. Since resistivity is a characteristic property of each earth material, different materials can be determined according to variations in resistivity.



Table 1. Resistivity values of common sediments

| Lithology       | Resistivity<br>values<br>(ohm-m) |
|-----------------|----------------------------------|
| Loess           | 15-40*                           |
| Till            | 15-45                            |
| Sand (dirty)    | 50-100                           |
| Sand (clean)    | 75-100                           |
| Sand and gravel | 50-200                           |
| Gravel          | 100-800                          |
| Shale           | 20-40                            |
| Sandstone       | 100-500                          |
| Limestone       | 100-500                          |
| Coal            | 1-1000†                          |

\* Higher when drained.

† Data from Parkhomenko, 1967.

The electrical characteristics of the specific lithologic units that overlie this site are not completely known. Table 1 lists the general types of sediments typically encountered in Illinois and their approximate range of resistivity values.

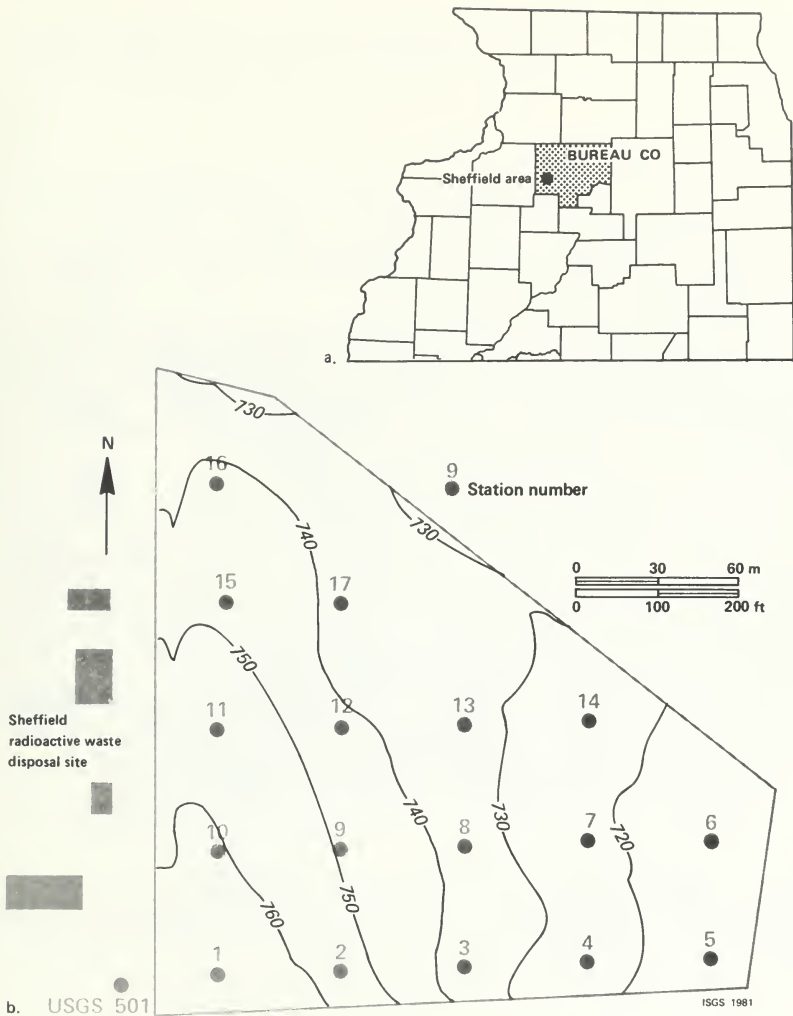
#### FIELD METHOD

Seventeen VES stations were occupied in a 45 by 45 meter (150 by 150 ft) grid arrangement. The Schlumberger electrode configuration was used in conjunction with a Bison Model 2350 B resistivity meter. Maximum current electrode separation was 63 meters (207 ft) except at some stations on the perimeter of the grid where fence lines and topography limited the maximum current electrode separation to 28 meters (93 ft). The L:l ratio was kept at 10:1. ("L" is the distance between the center and one current electrode; "l" is the distance between the center and one potential electrode.)

## RESULTS

The VES field curves were interpreted using Zohdy's (1973) automatic inversion program which assumes horizontal, homogenous, and isotropic layering of the subsurface. In this method, the observed VES curve is approximated by a Dar-Zarrouk (DZ) function (Maillet, 1947). The DZ functions or curves are themselves functions of the resistivity layering parameters—thickness and resistivity. From these parameters a theoretical VES curve is calculated by an inversion process and compared to the observed VES curve. The DZ curves are varied and new VES curves are calculated until the match between the observed and calculated VES curves falls within a prescribed tolerance interval. The number of layers in the resulting model (detailed solution) is always equal to the number of points used to define the observed VES curve. Equivalent solutions composed of fewer layers are determined by automatically smoothing the DZ curve of the detailed solution and inverting it (Zohdy, 1975). The method provides electrically realistic layer resistivities and thicknesses. Electrical sections are then constructed by plotting the electrical layers, with calculated resistivities and thicknesses, below the center point of the electrical sounding. These sections are close approximations to the actual geology. Because the final smoothing of the detailed solution is done automatically, an electrically equivalent solution may be introduced that does not directly conform to the geology.

Geoelectrical sections were obtained for all 16 stations and are plotted in five north-south profiles (fig. 1). In general, five resistivity zones are definable below the site. The first zone is a thin, surface layer with low to moderate resistivity values. The second zone has consistently moderate resistivity values and is fairly thick in the western, higher portion of the site, but is thin or absent to the east. The third zone is a high resistivity layer, which is also thicker in the western half of the site and becomes thin or absent to the east. Below this high resistivity zone is a fourth zone with low to moderate resistivity values. The fifth zone is a discontinuous zone with high resistivity values located below zone 4. When correlated from station to station, the upper surfaces of the two high resistivity zones (3 and 5) appear to be horizontal; but because



**Figure 1.** (a) This electrical earth resistivity survey was conducted in the Sheffield area of Bureau County, SW¼ NW¼ SE¼ Section 26, T. 16 N., R. 6 E. (b) Site topography (after USGS preliminary map, 1981). Contour data in feet above mean sea level.

the land surface slopes sharply to the east (fig. 1), they occur at depth below the western edge of the site and are at or near the surface in the east (fig. 4).

## INTERPRETATION

The first four electrical zones can be correlated with the geologic section derived from USGS well 501 (table 2). There is insufficient geologic data to interpret zone 5. It is probably a result of layering within the bedrock.

The resistivity values of zone 3 at each station are plotted and contoured on figure 2. The highest readings form a semicircular band around the western half of the site. The extremely high resistivity values at stations 1, 9, 12, and 15 may be caused by the presence of either very coarse sand and gravel or drained soil.

The sandy outwash of the Toulon Member was encountered at an elevation of 746 to 732 feet in well 501. Figure 3 illustrates the elevation of the top of zone 3 in the subsurface. The material in this zone forms a lens-shaped body in the western half of the site. A small extension continues eastward just below the land surface in the vicinity of stations 13 and 14, where sand and gravel was observed in surface gullies.

The depth to the top of zone 3 is shown on figure 4. The material in zone 3 is deeply buried in the southwestern corner of the survey area, but it is at or near the land surface in the central and eastern parts of the area.

Table 2. Electrical zones and their geologic equivalents

| Electrical zones | Resistivity (ohm-m) | Geologic equivalent                 |
|------------------|---------------------|-------------------------------------|
| 1                | 17-60               | Holocene soil or fill               |
| 2                | 41-53               | Peoria Loess and Radnor Till        |
| 3                | 84-880              | Toulon Member (sand and gravel)     |
| 4                | 9-56                | Hulick Till and Pennsylvanian shale |

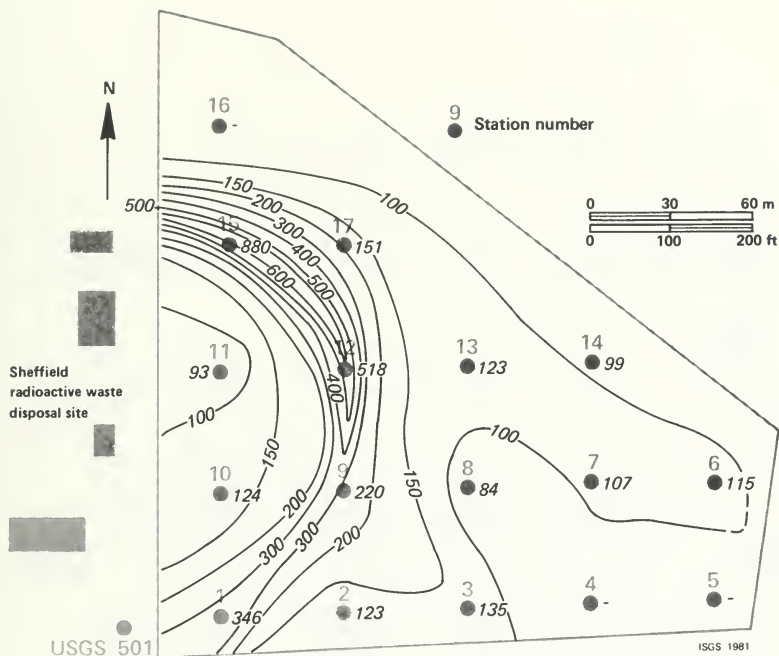


Figure 2. Resistivity (in ohm-meters) of zone 3 as calculated by Zohdy interpretation program.

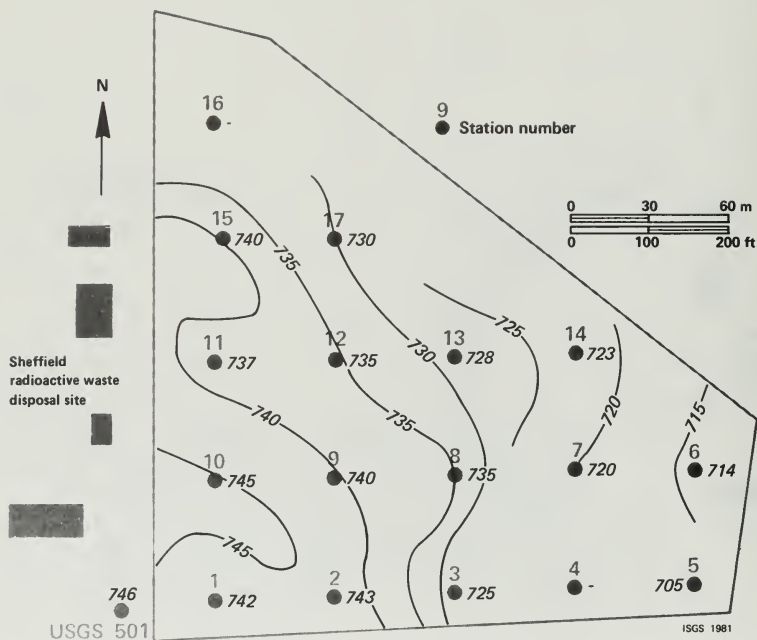


Figure 3. Elevation (in feet above mean sea level) of top of zone 3.

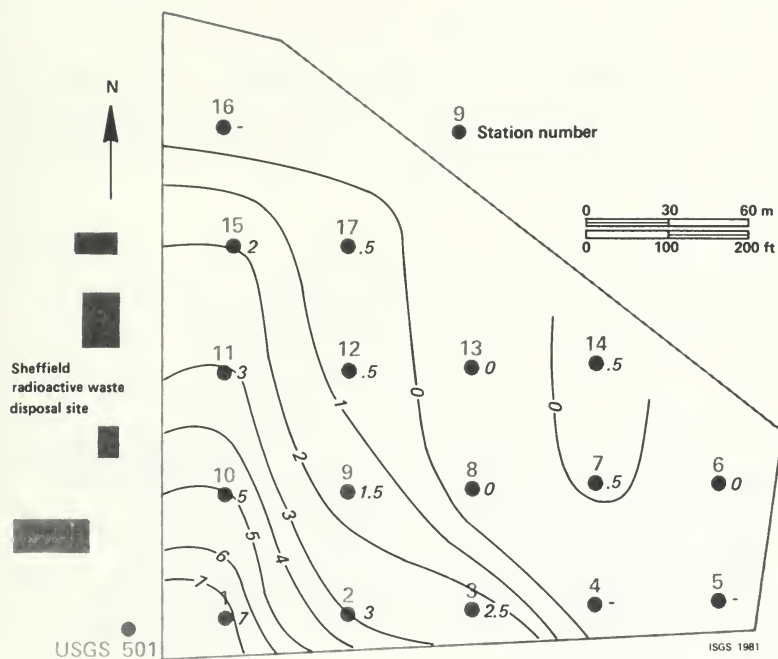


Figure 4. Depth (in meters) to top of zone 3.

The thickness of zone 3 at each station is plotted and contoured on figure 5. The thickness of this zone exceeds the depth of resolution of the field arrangement at stations 1, 2, and 10. At these stations, the true thickness is greater than the thickness shown on the map. Zone 3 is thickest in the southwestern portion of the site with a thin eastward extension.

The lens-shaped body of high resistivity material in the western half of the site is definitely a deposit of Toulon Member sand; however, the thin, surficial eastward extension is more problematic. It may be part of the primary deposit, but because of its smaller size as well as its position on the lower slopes of the hillside, it is probably a secondary deposit resulting from erosion of the main body.

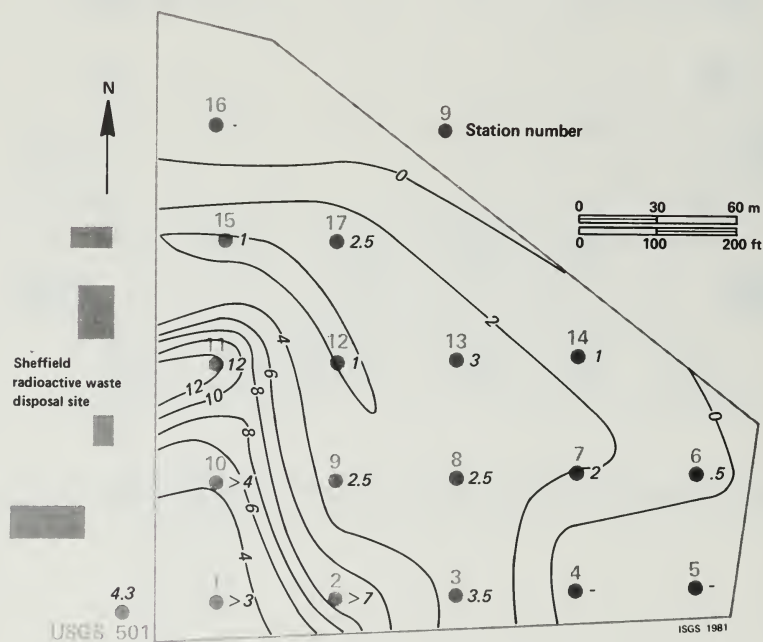


Figure 5. Thickness (in meters) of resistivity zone 3.



## CONCLUSION

The Toulon Member of the Glasford Formation encountered in bore holes on the Sheffield Disposal Site extends eastward into the resistivity survey area. Resistivity data indicate that it is thickest in the western portion of the surveyed area and thins eastward. Its extent can be best approximated by the 150-ohm-meter contour of figure 2 and the 730-foot contour of figure 3. A small tongue of high resistivity material extends eastward from the main body. Because this material lies close to the land surface, it is probably of secondary origin, caused by reworking of the glacial deposit by recent erosion.

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